

Title: Reverse Direct Detection: Cosmic Ray Tests of Dark Matter Scattering

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Abstract:

Reverse Direct Detection: Cosmic Ray tests of Light Dark Matter

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20-Jul-17

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Reverse Direct Detection: Cosmic Ray tests of Light Dark Matter

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Christopher Cappiello



John Beacom

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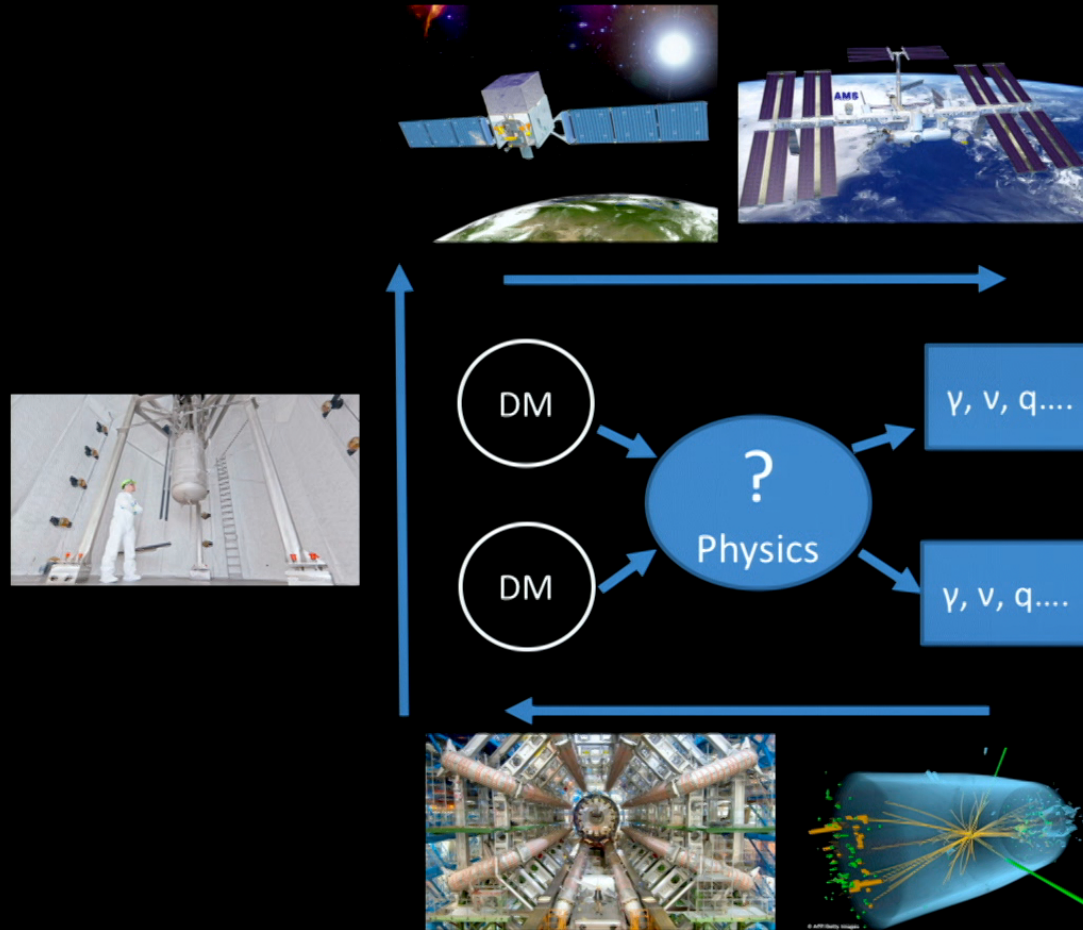


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Dark Matter Search Strategies

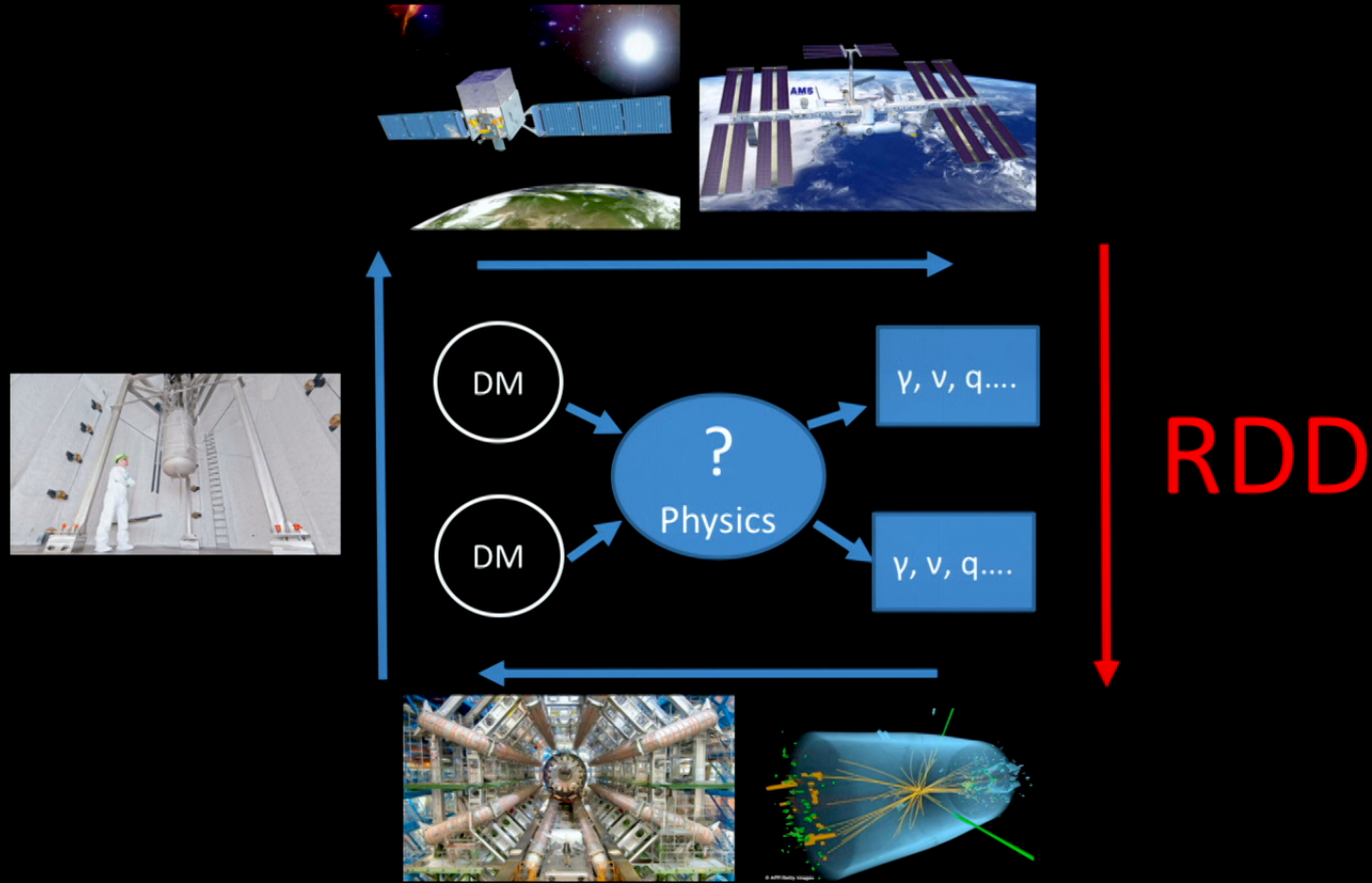


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Dark Matter Search Strategies



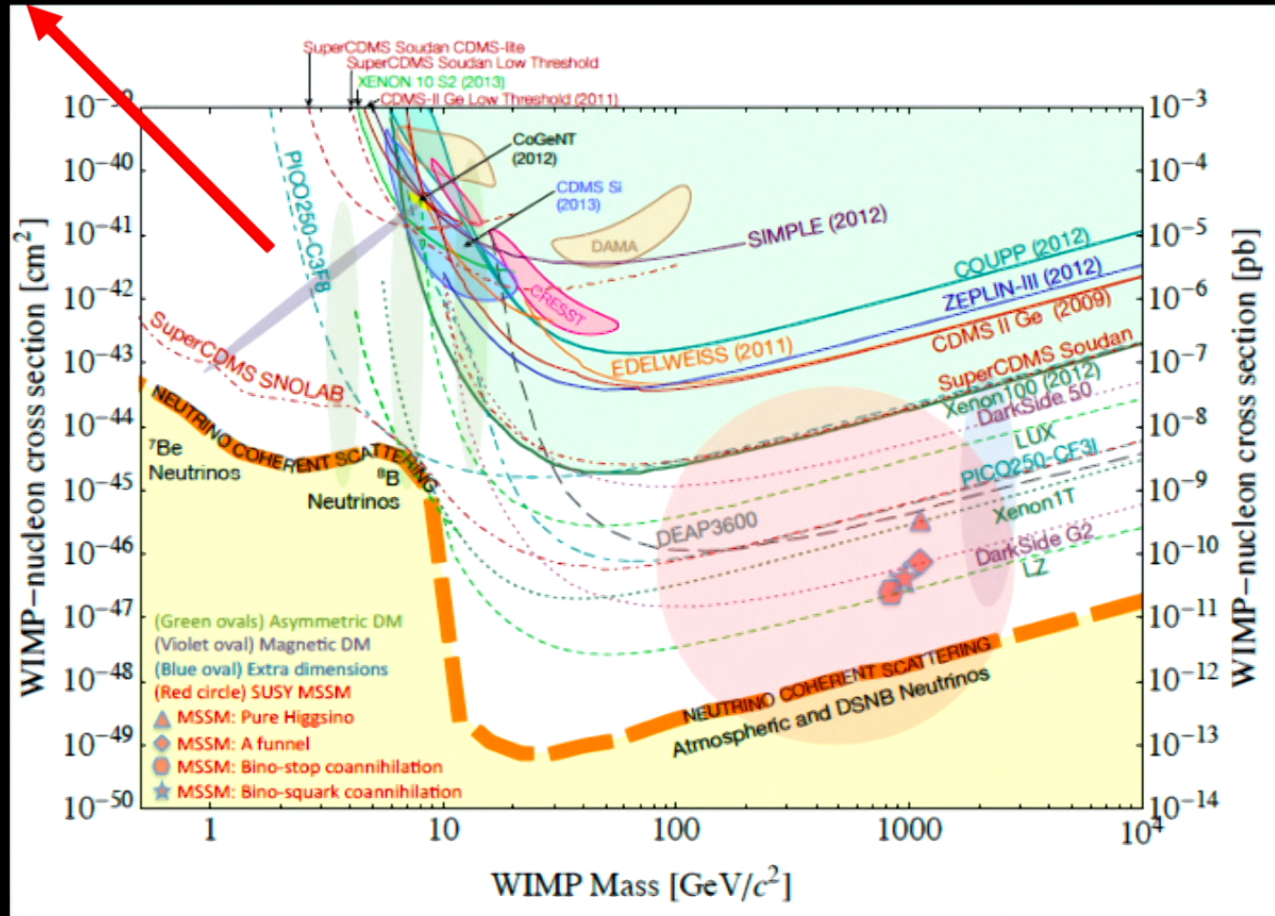
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Why RDD?



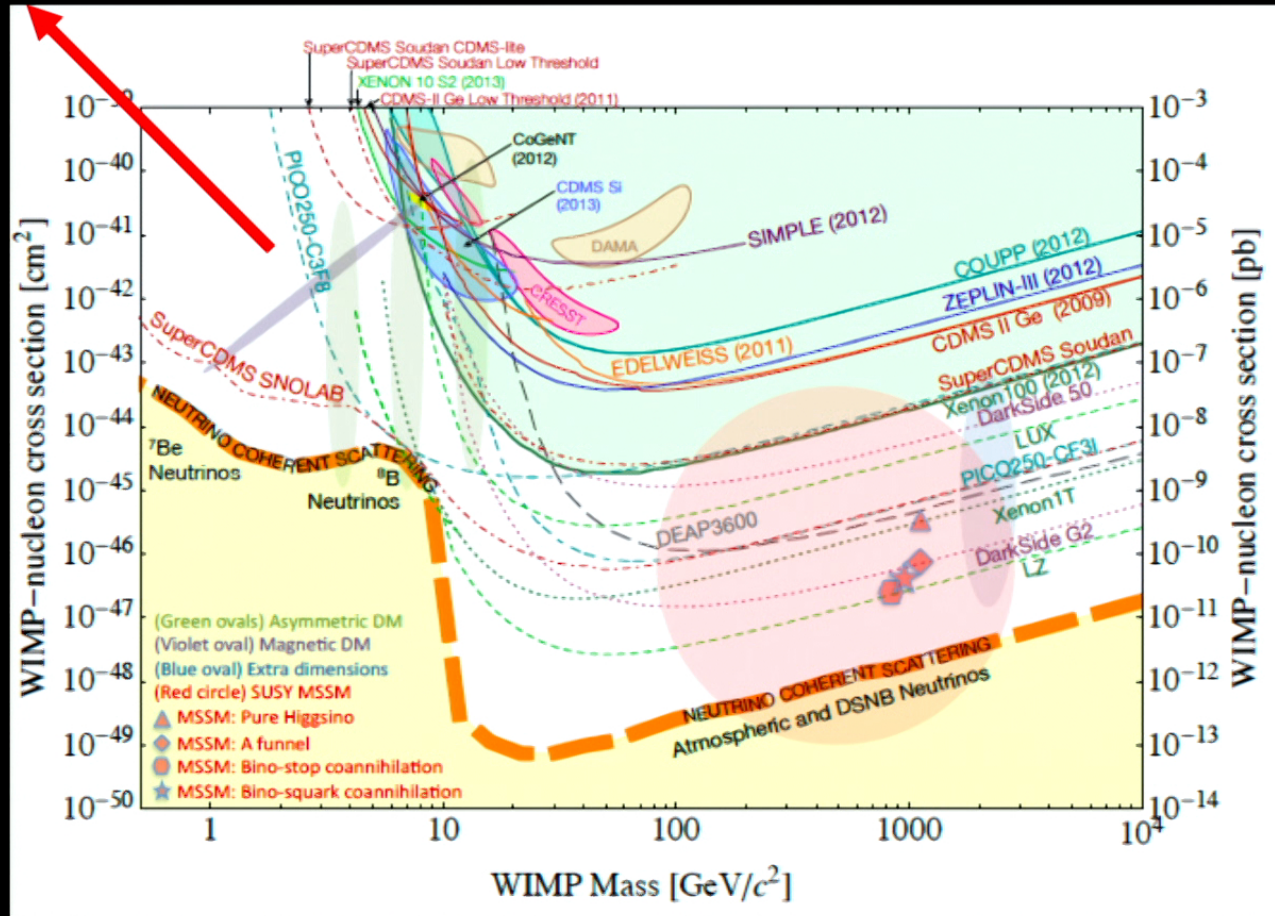
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Why RDD?



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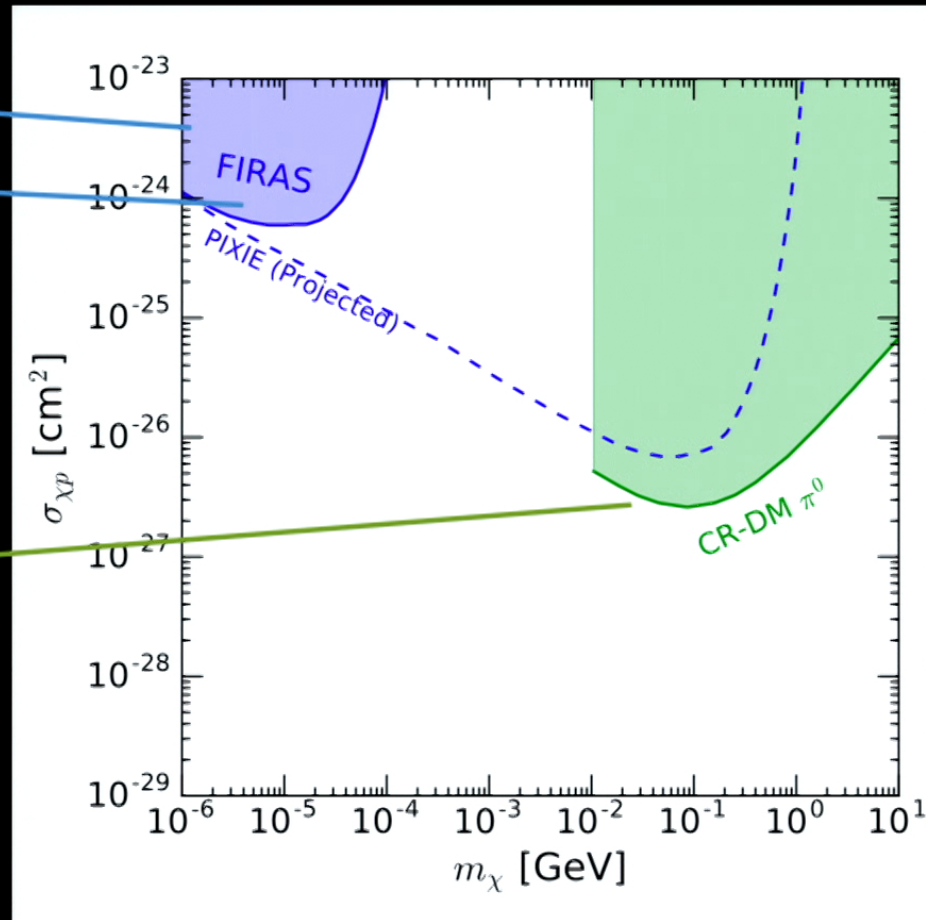
Light Dark Matter

- CMB spectral distortion

Ali-Haïmoud, Chluba, Kamionkowski
1506.04745

- Gamma rays from CR-DM inelastic interaction

Cyburt, Fields, Pavlidou, Wandelt
astro-ph/0203240



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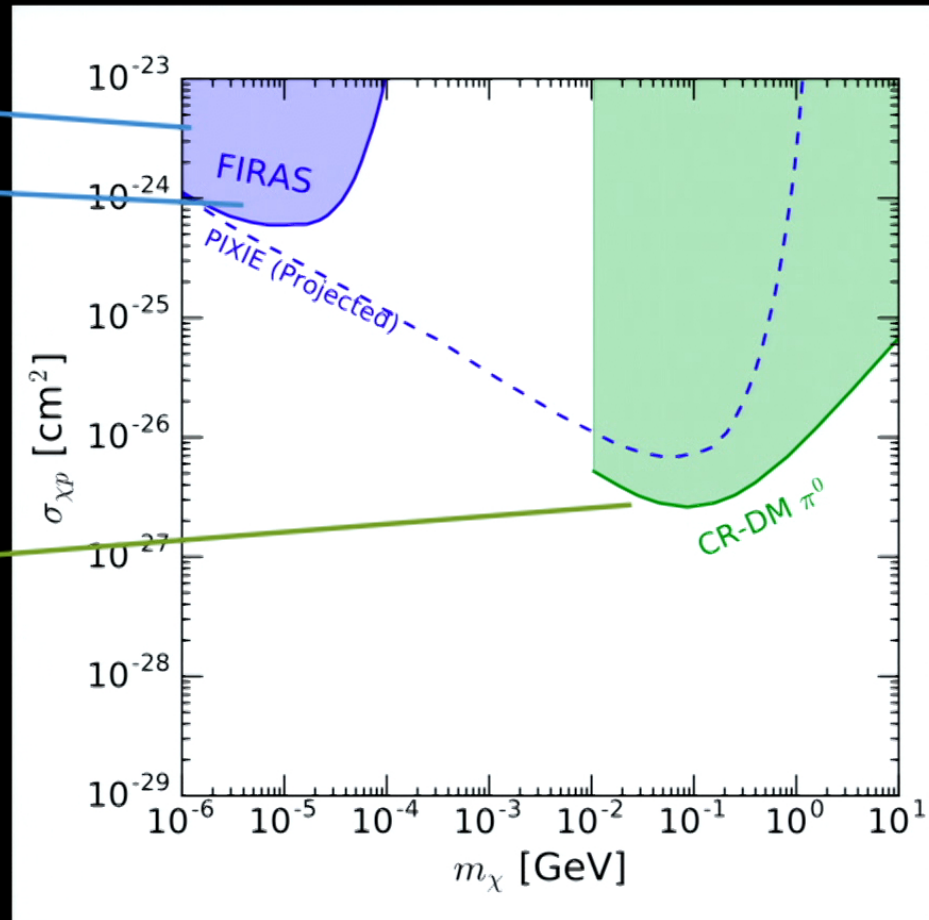
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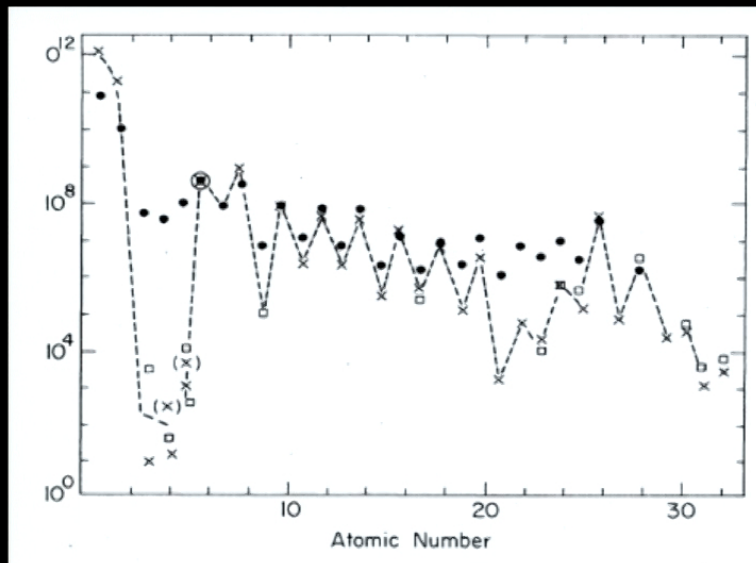
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Cosmic rays in the Galaxy

- Isotropy -> diffusion like propagation
- Secondary nuclei -> cosmic-ray interactions and confinement

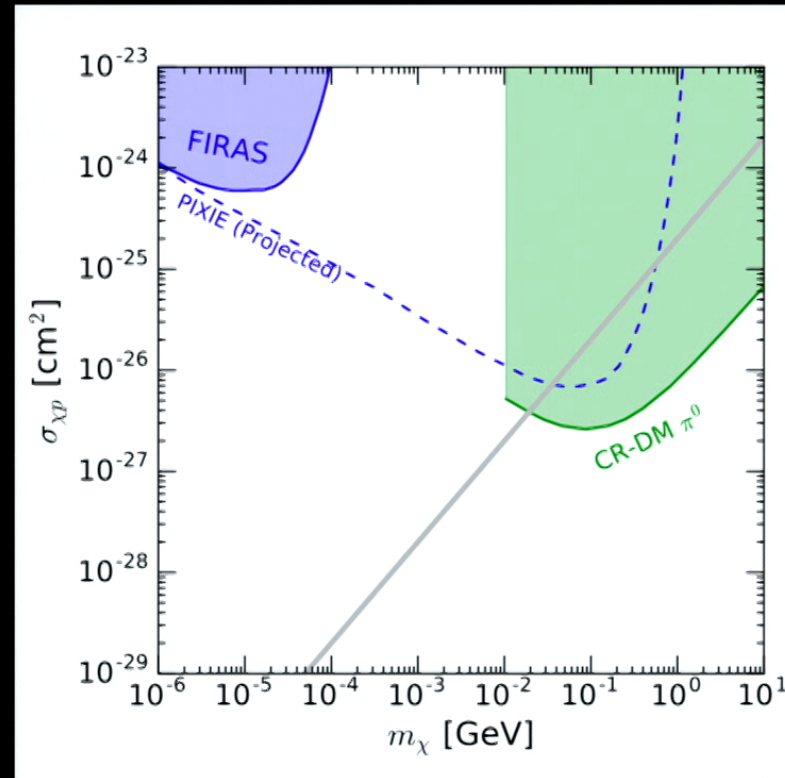


- **Cosmic-ray beam on DM target**

Ginzburg, Ptuskin
RevModPhys.48.161

Dark Matter column density

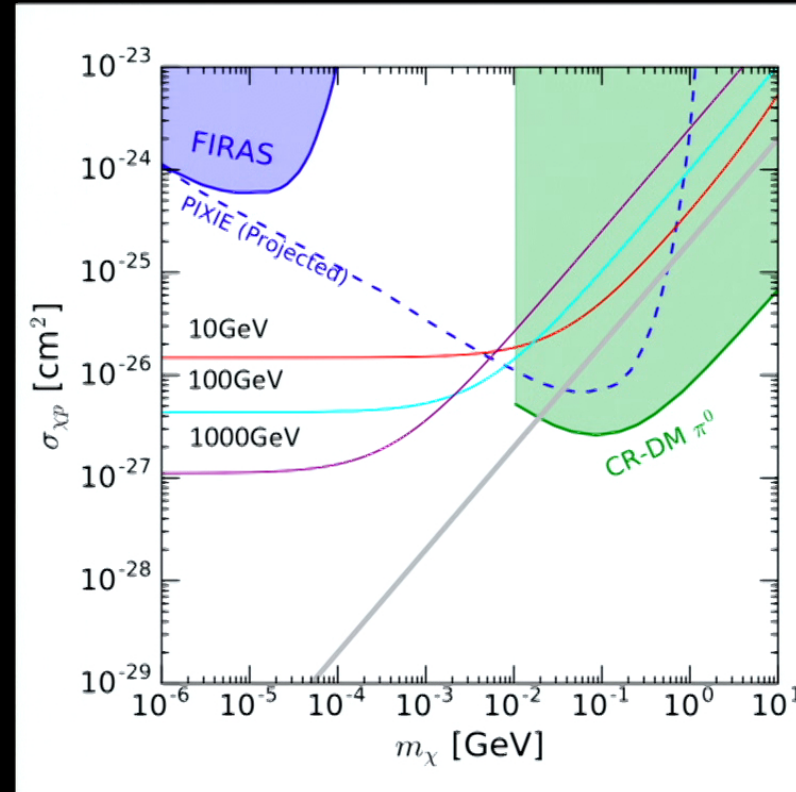
- Grammage $\sim 10 \text{ g/cm}^2$ @ 10 GeV
- \sim DM grammage
- Line of $\tau = 1$
- “Best possible” reach



Cosmic-ray energy loss

- Slightly better Order of magnitude estimate.
- Energy loss
- Order 1 energy loss

$$|\Delta\mathcal{E}| = \frac{4m_p(1 + \frac{\mathcal{E}}{2m_p})\frac{\mathcal{E}}{m_\chi} (1 - \cos\theta)}{(1 + \frac{m_p}{m_\chi})^2 + \frac{2\mathcal{E}}{m_\chi}}$$



A toy CR model with DM energy loss

- Protons
- The Leaky box approximation

$$\frac{N(\mathcal{E})}{T_{\text{esc}}} + \frac{d}{d\mathcal{E}} \left[\frac{d\mathcal{E}}{dt} N(\mathcal{E}) \right] = Q(\mathcal{E})$$

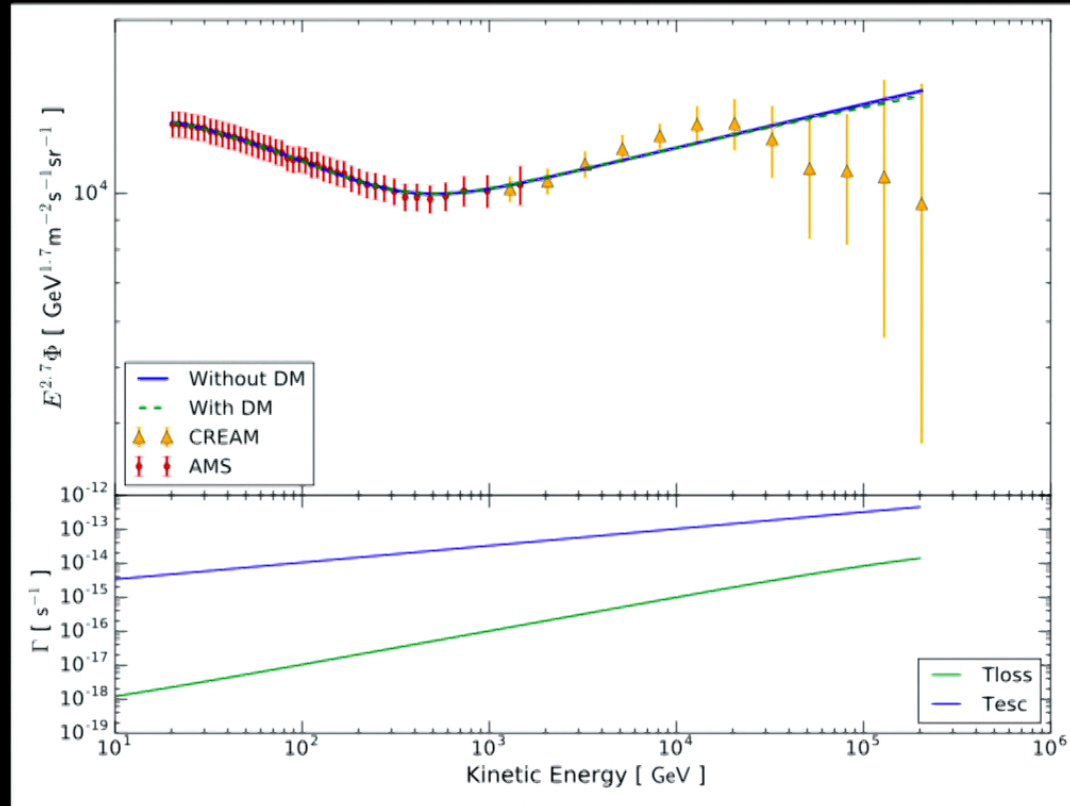
- Simple energy loss model
 - Elastic scattering
 - Energy-independent cross section

$$\frac{d\mathcal{E}}{dt} = c \frac{\rho}{m_{\chi}} \int_0^{\mathcal{E}_{\text{max}}} T \frac{d\sigma}{dT} dT$$

$$\frac{N(\mathcal{E})}{T_{\text{esc}}} - \frac{d}{d\mathcal{E}} \left[\frac{\mathcal{E}}{T_{\text{loss}}} N(\mathcal{E}) \right] = Q(\mathcal{E})$$

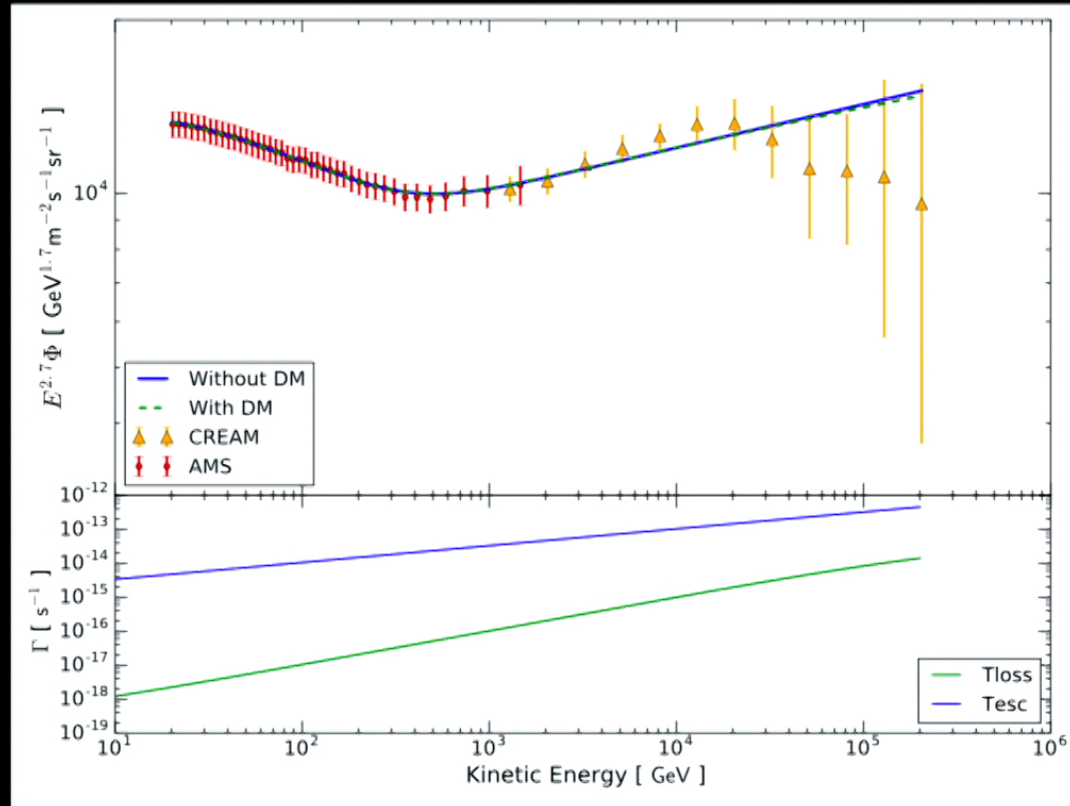
CR model without DM

- $\Sigma = 1e-29.0$
- $M_x = 1e-6$ GeV
- Cream + AMS
 - +5% systematic
- Broken power law injection



CR model without DM

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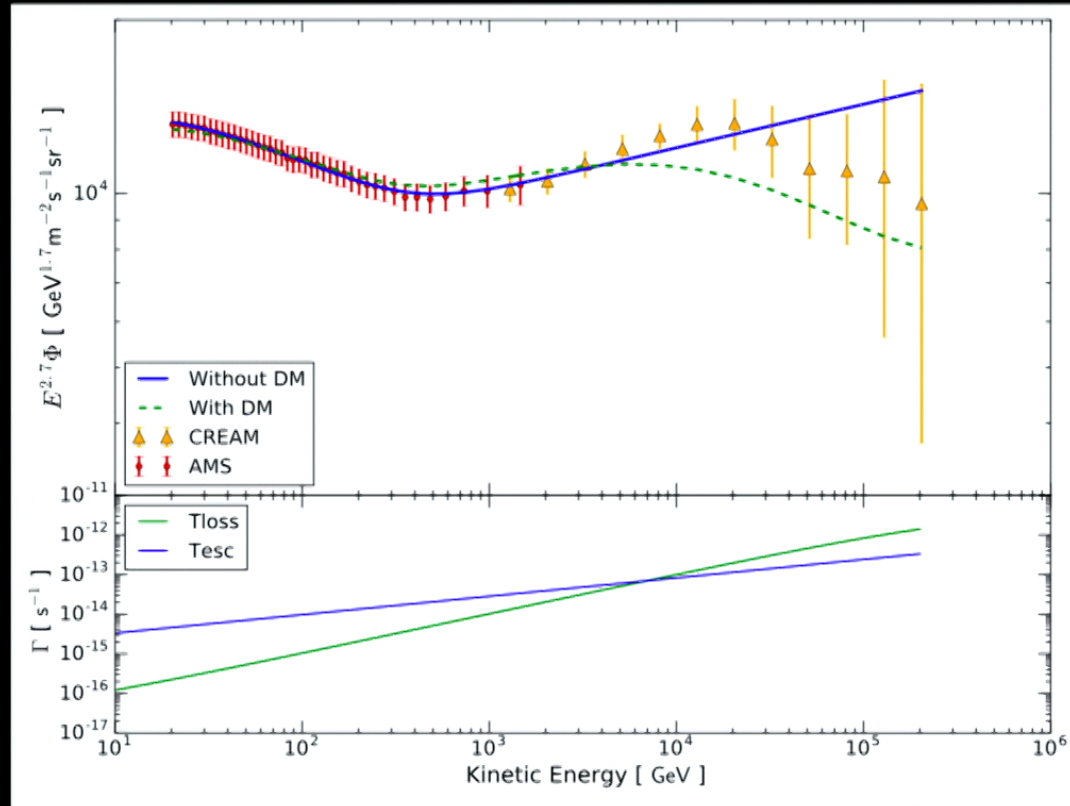
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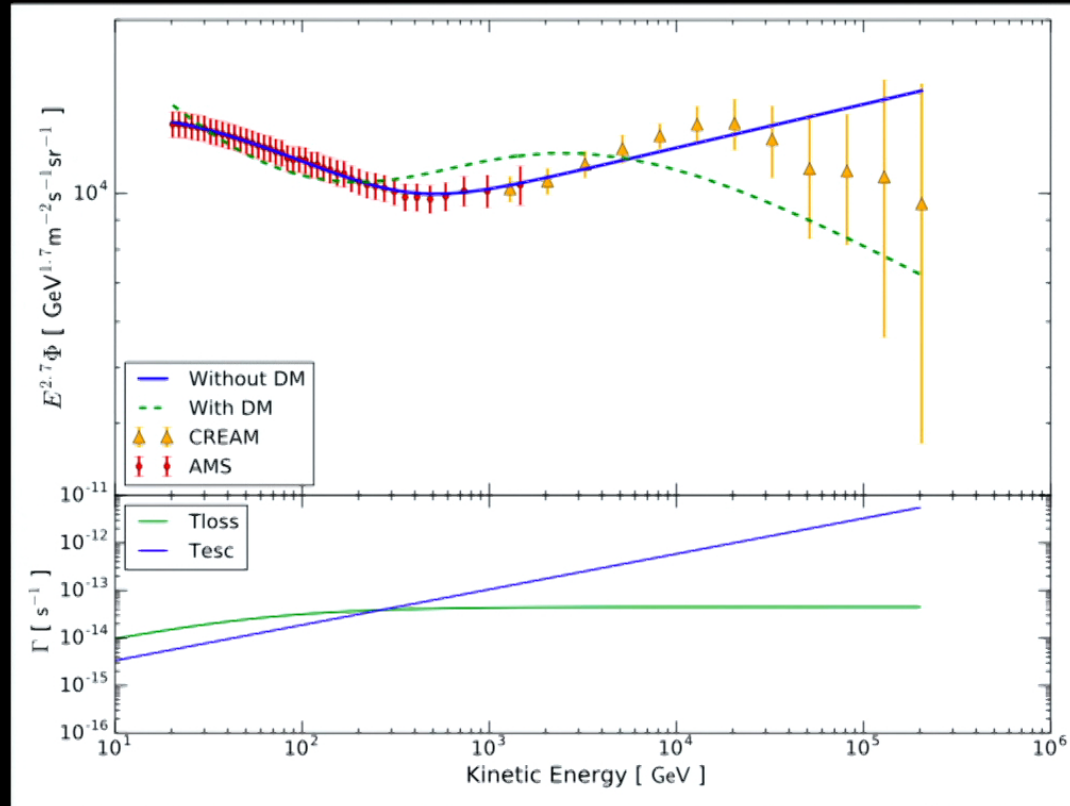
The effect of DM Scattering on CR

- $\Sigma = 1e-27.5$
- $M_x = 1e-6$ GeV
- Fix
 - Inject- index
 - Break-energy
 - Break- index
- Vary
 - Norm
 - Tesc index



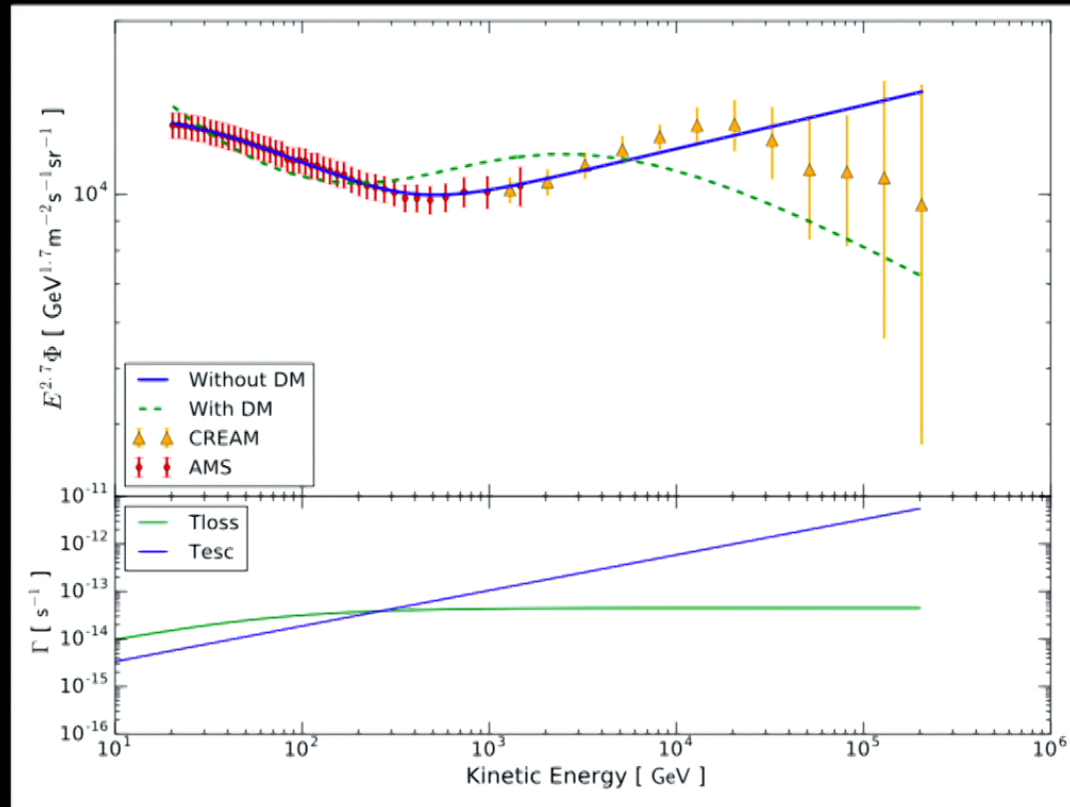
The effect of DM Scattering on CR

- $\Sigma = 1e-25.0$
- $M_x = 1e-2$ GeV
- Fix
 - Inject- index
 - Break-energy
 - Break- index
- Vary
 - Inject-norm
 - Tesc index



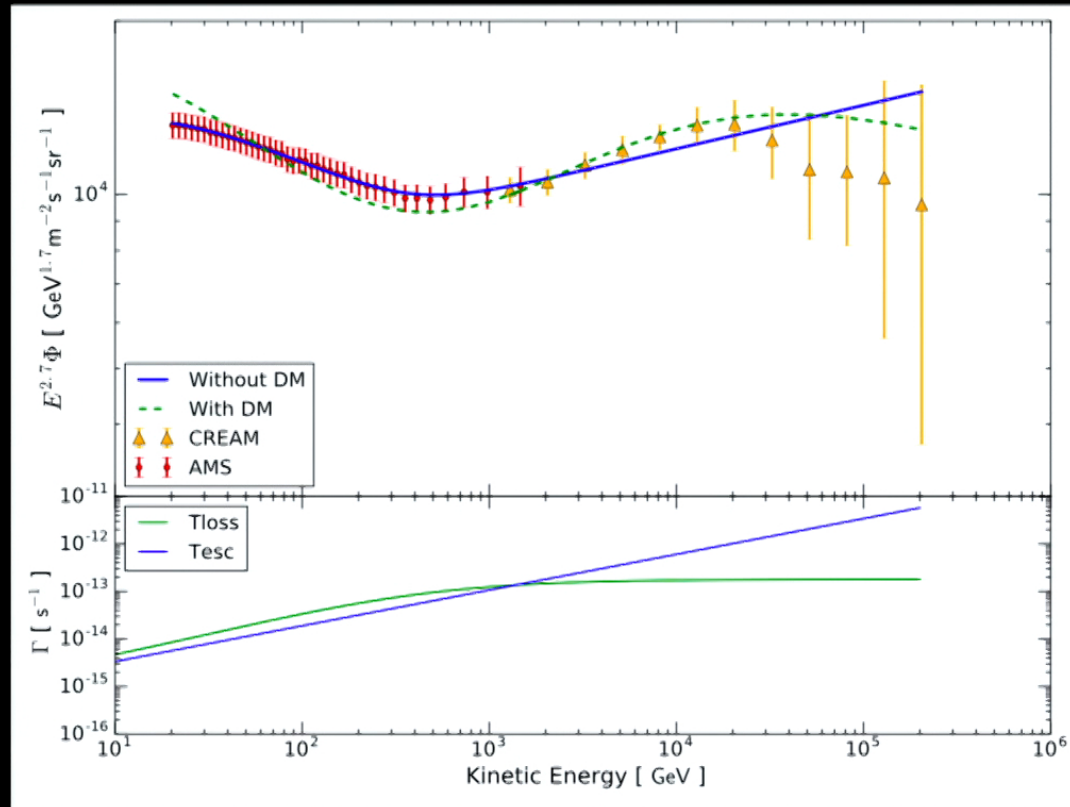
The effect of DM Scattering on CR

- $\Sigma = 1e-25.0$
- $M_x = 1e-2$ GeV
- Fix
 - Inject- index
 - Break-energy
 - Break- index
- Vary
 - Inject-norm
 - Tesc index



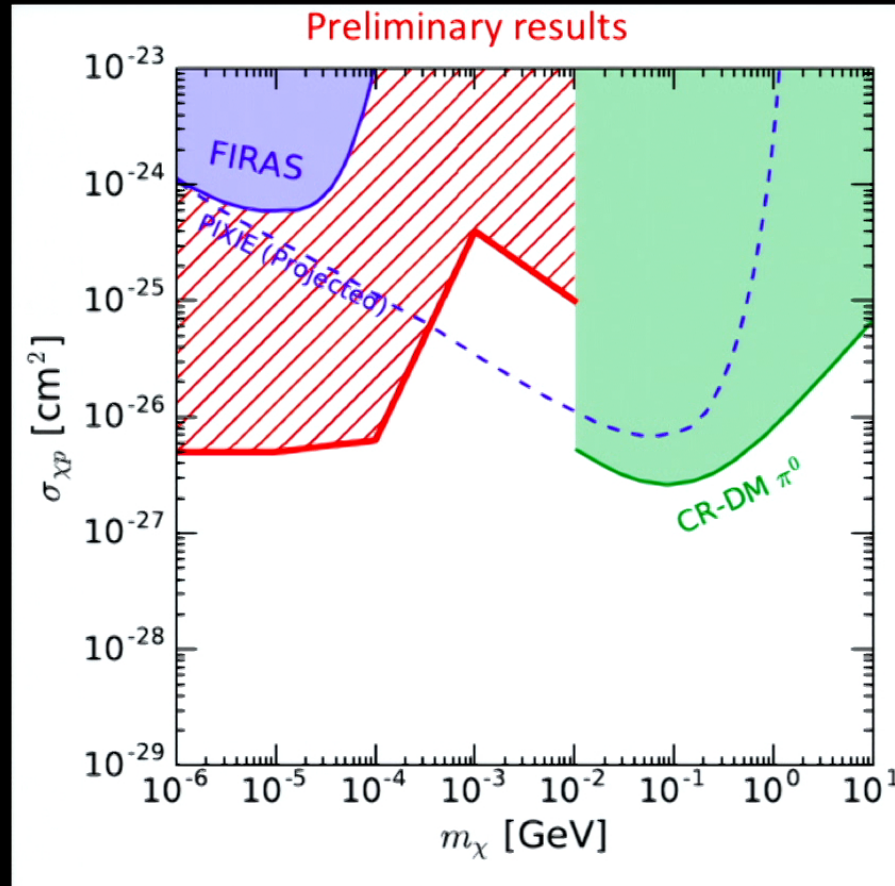
The effect of DM Scattering on CR

- $\Sigma = 1e-25.4$
- $M_x = 1e-3 \text{ GeV}$
- Fix
 - Break-energy
- Vary
 - Inject-norm
 - Tesc index
 - Inject- index
 - Break- index



Final result

- Fix
 - Break-energy
- Vary
 - Inject-norm
 - Tesc index
 - Inject- index
 - Break- index



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Summary

- CR - DM elastic scattering can induce CR energy loss
 - Spectral distortion
- New limit for light dark matter
 - Cover previously unexplored parameter space
 - Xsec too large for direct detection
 - Available now!
- More to follow!